UNITED NATIONS
ECONOMIC AND SOCIAL COUNCIL

Distr.
GENERAL
E/ECA/NRD/ERU/COAL/4/86
28 January 1986
ORIGINAL: ENGLISH

ECONOMIC COMMISSION FOR AFRICA

COAL IN AFRICA - BASIC PROPOSALS FOR ITS DEVELOPMENT

COAL POTENTIAL AND POSSIBILITIES FOR INCREASED COAL UTILIZATION

COAL IN AFRICA - BASIC PROPOSALS FOR ITS DEVELOPMENT

COAL POTENTIAL AND POSSIBILITIES FOR INCREASED COAL UTILIZATION

Table of Content

		Page
1.	Summary and Recommendations	1
2.	Background and Introduction	6
3.	Coal Potential, Production and Trade in Africa	7
	3.1 Overall Potential, Production and Trade	7
	3.2 Southern Africa	9
	3.3 North Africa	9
	3.4 Sub-Sahara Africa	10
4.	Increased Coal Utilization	12
	4.1 Substitution of Oil	12
	4.1.1 Power Generation	12
	4.1.2 Coal Gasification and Liquefaction	16
	4.2 Substitution of Wood Fuel	17
	4.3 Coal Exports	20
	4.3.1 Project Optimization	20
	4.3.2 Penetrating International Markets	25
5.	List of Reports and Documents	27
6.	Abbreviations as used in this Report	31

Summary and Recommendations

1. This report to the Conference of Ministers represents an important part of a sequence of publications under the collective topic: "Coal in Africa - Basic Proposals for its Development" and concentrates on the African

- "Coal Potential and Possibilities for Increased Coal Utilization".

Further publications under the mentioned collective topic are:

- "Inventory and Assessment of African Coal Resources, Production and Trade in the Context of Regional African Development" (as published by UNECA during the Regional Workshop on Energy Supply and Demand Projections through 1985-1990 in Africa, 25-29, November 1985)*, and

- "Operational and Organizational Aspects of Increased Coal Utilization" in Africa as being issued by UNECA as a technical publication under the Sub-programme on the Integration of Energy Policies into overall socio-economic development and growth policies.**

2. The overall African coal reserves and resources constitute a very large potential for future coal production in Africa for centuries to come. A recent inventory resulted in more than 168 billion tonnes of coal resources of which presently 75 billion tonnes are regarded mineable (in situ) (see footnote).

3. The Southern half of Africa, however, possesses much more coal resources than the northern part of the continent. This appears to be a general indication for the chances which the intra-African coal trade may have in the future, when the abundant Southern African coal resources will have been developed for export purposes.

4. This observation is also supported by the present production, export and import figures, which show that North Africa is importing approximately 3 million tonnes of coking coals already now from overseas sources in industrialized countries while its production in 1985 is severely restricted at 0.85 million tonnes of coal. The predicted development shows an even growing trend in this direction, namely at 6 million tonnes of imported coals in 1990, while production appears to grow to 1.6 million tonnes only.

---

* E/ECA/NRD/ESD/7
ECA/NRD/ERU/COAL/280/2/85 of 15 November 1985
** ECA/NRD/ERU/COAL/280/5/85 of 16 December 1985

Copies of these publications are available at UNECA, Natural Resources Division, P.O. Box 3001, Addis Ababa, Ethiopia.

5. A similar development is indicated in West Africa where despite abundant coal resources a growing import of coking coals is forecasted. Production is likewise estimated to grow considerably in Sub-Saharan States from 0.25 million tonnes in 1980 to 1.3 million tonnes in 1990. In view of the required coking coal qualities for steel production, which appear not be available in West Africa, this Subregion will probably continue to be importing such coal qualities.

6. It is expected that new Southern African coking coal and steamcoal developments can supply such qualities and may satisfy at least part of the North and West African coal import demand in the long term future.

7. Up to the year 1990, however, expectations for coal exports by developing African countries to overseas customers appear to be slim. Due to major time requirements for the development of coal export facilities and infrastructures and due to some geographical constraints, major coal export developments of Southern African developing Nations will only materialize after 1990. African Nations are, however, predicted to import more than 8 million tonnes annually by 1990.

8. For practically all countries in the world that cannot use indigenous oil for domestic use, the development of coal fired powerplants for oil substitution has been a predominant issue in the strategies for energy development. In addition, many African countries can reduce the loss of their hard earned foreign currency by the substitution of imported oil by indigenous fuel including coal.

9. Some African countries predominantly where coal is already available have initiated action in this respect. But also in countries where coal is not sufficiertly available, coal fired powerplants appear to be part of the long-term energy strategy if they can be positioned at the coast and be supplied by competitive overseas coal imports. The anticipated steeply growing industrialization of African countries will accellerate the development of additional energy sources in Africa, a major part of which will have to be based on coal and lignite.

10. Comprehensive resource identification and evaluation programmes in close co-operation between the Geological Surveys of African countries, international scientific institutions and experienced coal mining industries at national, subregional and regional levels are urgently recommended, predominantly for African countries where no or only minor coal and lignite resources are known to date. These exploration and research programmes usually result in general assessment and pre-feasibility studies which represent the last stage when the scientific emphasis should be shifted towards a more practical

engineering and economically oriented approach. This would lead into the feasibility assessment and planning of the mineplant and infrastructure. In all cases this should be undertaken by experienced mining operating and specialized companies with the support and backing of the respective utilities and under the observation, co-ordination and monitoring umbrella of the governments concerned.

11. Modern combustion technologies are to be checked as to their applicability in Africa. Air cooling systems and the reduction of sulphur and nitrogen oxide (NOx) are of predominant concern. Most important new technologies for possible use in Africa appear to be atmospheric pressure fluidized bed combustion and stabilized coal-in-oil suspensions which are utilized in for oil designed power-stations that cannot otherwise be converted to coal. Fluidized bed combustion facilitates the use of high ash and sulphur containing coals or even discards from a preparation plant, which appears to be of utmost importance while optimizing the use of coal for export purpose (washed product) and power generation (discards or middlings).

12. Other important areas of oil substitution are the alternatives of coal gasification and liquefaction. Due to market and economies of scale related exigencies, a wide spread application in developing African countries does not yet seem to be opportune. One possible application appears to be, at the present level of commercialized technologies, coal gasification with subsequent synthesis for ammonia (fertilizer production) and gasoline production. The direct hydrogenation method, however, has not yet been commercialized and can only be recommended to be considered if the implementation of the project should be envisaged at a time later than the year 2000.

13. The Substitution of Wood Fuel by coal appears to be of paramount importance in many African countries where desertification progresses rapidly around villages and towns. The use of coal as household and small industry energy sources is widespread over the globe and should also be promoted by African States in order to help reducing the often devastating wood fuel consumption. This appears to be fully in line with the Lagos Plan of Action which calls for diversification of energy sources. Studies of UNDP and the World Bank have shown that coal is well competitive in comparison with commercially traded fuelwood and other energy sources used in households. However, these findings do not consider that a major part of firewood in African countries is just being retrieved from the bush surrounding villages and towns. Consequently, the "price" for "collected" firewood is not comparable with the price for coal which cannot just be "collected" but must be produced at some costs.

14. If African countries do not want to restrict themselves to aiming at a woodfuel substitution of only approximately 10% (which appears to be the woodfuel consumption of a solvent minority) then, they should seriously consider effective incentives for the increased consumption of household coal, which means: massive subsidization.

15. Also the cultural and social obstacles against a large scale introduction of coal fired stoves into African households must be taken into consideration. A carefully planned and executed education and information campaign supported by coal stove demonstration centres, should be linked with the distribution organizations to ensure efficacy of such a woodfuel substitution programme.

16. The oversupply situation of the international coal markets shows that as a reaction to the "oil crisis" in 1973, the coal export industries all over the world have energetically increased the establishment of new coal export capacities. These are producing now in a very competitive environment at severely depressed coal prices.

17. Moreover, technical innovations in the areas of land and sea transport of bulk materials (unit trains, large shipsizes of above 100,000 dwt), as well as of the size of bulk loading facilities in harbours, indicate that in most cases only large scale coal export mines will in all probability be competitive and in the position to secure a decent return on the growing investment for mine plant and infrastructure.

18. Newly to be established coal export facilities in Africa, as elsewhere in the world, require the exploitation of all possible project optimization measures and a certain minimum production size to achieve maximum economies of scale and a sufficient profit in order to pay back for the major amounts of infrastructure investments that are unavoidable for the penetration of the market under todays competitive conditions.

19. An important possibility to maximize the earning power of coal export projects is suggested by using the rejects of the preparation plant for power generation and coal gasification (Fertilizer production via ammonia synthesis). It would probably be prudent to check whether the available markets for such a power generation and fertilizer production should limit the coal export project size in view of an optimization effort.

20. Optimization does, however, not mean that highly mechanized mining methods should in any case be pursued, especially not for small and medium scale underground coal mines. It is important to recognize that the operating costs have inter-alia to be minimized by applying a minimum of investments and equipment installations. This means for small and medium sized underground coal mines that low cost hand got mining, if effectively managed, can successfully compete with highly mechanized mines of a similar production size.

21. A most important factor for project optimization, however, lies in the successful selection and involvement of an experienced operating company with a proven track record in high performance - low cost coal mining operations and with the backing of an efficacious marketing organization. Moreover, a conducive politico-economic climate may be regarded a further precondition for the attraction of international coal consumers and investors that must have confidence in the longterm viability of the project in order to participate in its envestment.

22. Despite the very demanding prerequisites for the implementation of a major coal export project in Africa, there may, in fact, be realistic chances for successfully penetrating the international coal markets if a professional and pragmatic approach were adopted. The geographically favoured countries may have the best chances with their specific coal brands, e.g.:

- Mozambique with excellent quality coking coal and with low sulphur steam coals,

- Madagascar with low sulphur steamcoals, and

- Swaziland with low sulphur Antracite and Semi-Antracite.

23. The landlocked Southern African countries may have to wait until the year 2000 due to the long railway distances and costly infrastructure investments which appear to be prohibitive for the build-up of major coal export capacities in these countries within the intermediate term future.

24. A most important approach to aggressively penetrating the international coal markets is the attraction of potential customers to directly participate in the financing and development of coal export projects by the acquisition of shares in the mining ventures. In this way, the participating project partners do not only acquire the right to receive a certain share of the production, but they also would have to accept the obligation to take a minimum share of the production and to pay for their share of the operating costs. The risk of the project should be minimized in such a way for which a suitable form of organization would be the joint venture in which the Government which owns the coal in the ground also participates and contributes.

25. Concluding, it can be expected that with an appropriate professional and pragmatic approach there appear to be ways and means to implement African coal export projects even under todays depressed market conditions.

2. Background and Introduction

26. UNECA concluded an Agreement with the Federal Republic of Germany in August 1984 for the delegation of an expert on coal development in order to enhance coal development in Africa and to pursue the following objectives:

- To actualize the intended inventory on coal resources, production and trade in Africa;
- To give advice and to assist member States in their endeavour to substitute environmentally destructive wood consumption and expensive coal and oil imports by the establishment of indigenous coal production; and
- To advise and to assist member States in their plans and actions to develop coal production facilities for coal export purposes where feasible.

27. The author was delegated from the Federal Republic of Germany to UNECA in Addis Ababa as a Regional Adviser for the development of African coal resources under the mentioned agreement.

28. This paper is based on information collected during two missions undertaken to Southern African countries. During these missions and in the course of subsequent follow-up work, advice was given to the member States in that subregion with regard to their respective action programmes in conjunction with the specific coal development activities in their areas.

29. The future work programme will include further missions to North and West African States during 1986 and exchange of information with coal and energy related international institutions and further missions to Central and East African States during 1986/1987. A Regional Workshop on the Development of Coal Resources in Africa will be organized for the member States to review the results of the work currently being undertaken and to propose strategies for African coal development and utilization.

30. This report represents an important part of a sequence of publications under the collective topic: "Coal in Africa - Basic Proposals for its Development" and concentrates on the African

- "Coal Potential and Possibilities for Increased Coal Utilization".

Further publications under the mentioned collective topic are:

- "Inventory and Assessment of African Coal Resources, Production and Trade in the Context of Regional African Development" (as presented by UNECA during the Regional Workshop on Energy Supply and Demand Projections through 1985-1990 in Africa, 25-29, November, 1985) (41), and

- "Operational and Organizational Aspects of Increased Coal Utilization" in Africa as being issued by UNECA as a technical publication under the Subprogramme on the Integration of energy policies into overall socio-economic development and growth policies (52).

31. As the missions had been undertaken only to Southern African countries, the inclusion of interim information and figures for the other subregions into the provisional inventory should be seen as a temporary demarcation of orders of magnitude, which has been undertaken to show the major thrust of the developing coal mining economies in various sub-regional parts of Africa. Such a provisional juxta-position, as published on 15 November 1985 (41), was made in order to enable the reader to draw certain development related conclusions. It is the intention also of this study to accentuate inter-related African development opportunities and to expand on certain operational and organizational aspects for its implementation.

3. Coal Potential, Production, and Trade in Africa

3.1 Overall potential, production and trade

32. Consistent with recent inventory efforts, Africa possesses a coal potential that exceeds the presently known figure of 168 billion tonnes of coal in situ (41). Of this figure, there are 75 billion tonnes in situ regarded as "mineable reserves", that could be exploited under current technical and economic conditions. It appears worthwhile to note here that only a portion of this figure will ever be recovered as "run of mine" (ROM) tonnage, i.e. lifted to the surface by various mining methods, and again, a portion of the ROM coal will in many cases at the surface be washed down to a saleable product at a certain yield. Openpit mining recovers more coal (e.g. 80-90%) than underground mining (e.g. 25-70%), and coking coal for steel production will be washed to higher quality specifications which means at a lower yield (e.g. 30-70%) than steam coal for power generation or industrial use (e.g. 50-80%). The quality requirements for exported coals, which normally must travel over long distances, are, of course, much higher than for coal which is used for local consumption. Powerplants at the mine mouth often use Run of Mine coal or even discards from the washing process. The coal deposits in Africa are mainly of Permian age and have generally a relatively high ash content which must be reduced by washing in order to obtain the required quality specifications.

33. It is resulting from these circumstances that only approximately 10-20% of the aforementioned mineable reserve figure will finally end up in form of saleable coal products. Even such reduced reserve figure, however, constitute a very large potential for future coal production in Africa for centuries to come, not withstanding the expected growth of the presently low production figure in developing countries. Moreover, estimates of reserves and resources are representing only the status of the present knowledge and will still increase in the foreseeable future with the results of further exploration work or at improving market conditions.

34. The overall production of African coal is amounting to approximately 170.5 Million tonnes in 1985. Of this figure approximately 40.65 million tonnes appear to be exported of which approximately 40 Million tonnes most of it being steam coal are being shipped to overseas customers in industrialized countries. In 1990, 234 Million tonnes are expected to be produced (6.5% growth per year) of which 65 Million tonnes will be exported in the international coal market. Developing African Nations are producing approximately 5.5 Million tonnes of coal in 1985 and expect to increase this figure to 8.9 Million tonnes in 1990 (10% growth per year). Only slightly more than 0.65 Million tonnes report to intra-African trade in 1985, which will be increased to 0.83 Million tonnes in 1990 and which will entirely be covered by the Southern African Subregion (see below).

3.2 Southern Africa

35. The above-mentioned inventory (41) demonstrates, that the Southern half of Africa possesses much more coal resources than the northern part of the continent. This appears to be a general indication for the chances which the intra-African trade may have in the future, when the abundant Southern African coal resources will have been developed for export purposes.

36. The SADCC countries of Southern Africa are recording a total coal potential of more than 48 billion tonnes of which 17.3 billion tonnes fall into the mineable category (see above definitions). The coal production figures of SADCC countries total at nearly 3.9 million tonnes in 1985 of which 17%, 0.65 million tonnes, are being exported to other African countries.

37. The production increases as expected for 1990 will probably reach the level of approximately 5.8 million tonnes representing an annual growth of 8%. The expected growth of intra African coal exports within the subregion is estimated to be 5% per year until 1990, reaching a figure of approximately 0.83 million tonnes.

38. The expectations for coal exports by developing countries to overseas customers in industrialized countries will remain small until 1990. Due to the major time requirements for the development of coal export facilities and infrastructures and due to the geographical and other constraints of some potential exporters, major coal export developments of Southern African developing Nations will only materialize after 1990 according to present information.

39. The most favourable conditions for exports from the aspect of coal qualities are noticeable in Mozambique, but probably also in Madagascar, from a logistical point of view. Unfortunately, the infrastructural preconditions (rail, harbour) are not yet developed and will require major investments. These, on the other hand, necessitate major quantities for coal exports in order to secure payback of these costly investments.

3.3 North Africa

40. As mentioned before, the coal reserve figures in North Africa are much smaller than those in Southern Africa and amount to approximately 1.3 billion tonnes for the total coal potential of which only 0.246 billion tonnes are deemed to be mineable reserves. Also the expectations for further coal discoveries in the future appear to be modest.

41. The coal production figures in North African countries have partly deteriorated in recent decades. Major efforts are being undertaken to increase or to establish new indigenous coal production. However, the much smaller reserve and resource potential does not offer too optimistic expectations.

Presently, only Morocco is recording a coal production of 0.85 million tonnes in 1985 which is intended to be increased to 1 Million tonnes in 1990.

Egypt is developing its indigenous coal production and expects 0.6 Million tonnes by 1990. Algeria intends to resume its previously arrested production by 1990. The North African countries will apparently become the main potential intra African coal importers of steam and coking coals. As mentioned above, the southern and eastern African countries including Madagascar are the potential coal exporters of steam and coking coals.

42. North African countries are already now major coal importers. However, the sources for their coal imports are industrialized countries, as e.g. USA, USSR, Western Germany and Poland. One important reason for this is the lack of sufficient quantities and adequate coal qualities in North Africa. Specifically the steel industries of Egypt and Algeria require coking coal qualities which are not available in North Africa. However, also major steamcoal imports are anticipated in the not too distant future. In 1985, there are approximately 3.3 million tonnes of coal being imported into North African countries. In 1990, the predictions amount to nearly 6 million tonnes which means a rate of increase of more than 12% per year. Further increase of the demand for imported coals are anticipated in the intermediate and longterm future, not only for steelmill expansions but also for the establishment of coal based powerplants (Egypt and Morocco), which will offer important opportunities for intra African trade, when Southern African countries will have developed their abundant coal potentials for export purposes.

3.4 Sub-Sahara Africa

43. All those countries which are situated outside the SADCC organisation south of the Sahara have been included into this subdivision, which could not be visited to date but which are expected to have some coal potential. However, there is no claim for completeness, and the intention was to include into this report the available data and known aspects of the major coal bearing countries of this category (41).

44. The remarkable coal export potential of Madagascar has already been mentioned. Unfortunately, it could not yet been developed to its possible extent. Other countries such as Nigeria, Niger and Zaire are producing some smaller quantities for their indigenous consumption, mainly for power generation.

45. In the Subsaharan subregion the low level of production is not due to the lack of coal resources, as the situation in North Africa appears to be, but apparently due to the lack of development. Naturally inherent chances for the development of increased coal production appear to be existing in some of these countries, and ways and means must therefore be found to accelerate such development. General guidelines will be presented in ensuing sections,

but final advice and assistance can only be offered after having studied the local conditions "at the coal face".

46. The coal resource potential of this group of countries appears to be much larger than the known figure of 5.4 billion tonnes. The chance that future exploration work will disclose new coal resources and reserves, possibly nearer to population centres (Niger!) than to date, does not seem to be remote. The presently estimated figure of mineable reserves at 1.7 billion tonnes in situ appears to be modest as well. The major contributions to this figure are from Nigeria and Zaire, where major exploration programmes have been undertaken and appear to be in progress.

47. The overall production of this group of countries has been comparatively small during recent years at possibly around 0.25 million tonnes in 1980. Intended increases could reach approximately 1.3 million tonnes in 1990 at a projected growth rate of approximately 18% per year.

48. Nigeria intends to (or does already) import major quantities of mainly coking coals, due to the fact that the qualities required for steel production are not (or not yet) available in this country. Imports of up to 2 million tonnes are anticipated by the year 1990. However, precise figures have not yet been available and will mainly depend on the commissioning and expansion of the new steeelplant at Ajaokuta which was intended to start production in 1985. Zaire also imports coal and coke, but is receiving it from Zimbabwe.

49. The overall import figures for this sub-Sahara group of countries amounted to 400 million tonnes in 1980 and could possibly reach 2.2 million tonnes in 1990 according to a growth rate of 18% per year, similar to the aspired growth of coal production (see above). This anticipated steep growth of coal demand in Western and Central African countries indicates that major efforts will have to be made to increase coal production significantly. This refers also to coking qualities, and also West Africa should consider Southern African coking coals for imports in the future, as soon as Mozambique coking coals, which possess certain features of the required qualities, have been developed for exports.

50. It is significant to mention that Niger recently installed a coal fired powerplant for supplying electricity to its Uranium mines at Arlit and Akokan (1000 Km north of Niamey). This powerplant consists of two blocks each of 13.8 MW and applies the relatively new method of low pressure fluidised bed combustion. It will be interesting to observe its performance during the years to come because fluidized bed combustion could be an appropriate answer to sulphur rich African coals and discards (see below Section 4.1.1).

4. Increased Coal Utilization

4.1 Substitution of Oil

4.1.1 Power Generation

51. The development of coal fired powerplants for oil substitution has been a predominant issue in the strategies of energy development, practically in all non oil producing countries in the world. And even in oil producing countries, coal fired powerstations are generally expected to produce cheaper electrical power in the long run than from oil at itscurrent level of prices. The advantage of the use of coal for electrical power generation will even increase as the availability of oil is predicted to decrease during the early part of the next century (40).

52. Many developing countries in Africa find themselves in a situation of constrained foreign currency availability, so that the substitution of imported oil by indigenous fuel is, in fact, of vital importance. However, this is not a specific requirement for developing countries alone. All major industrialized nations introduced strategies to reduce their oil consumption for power generation since the mid seventies. This is specifically true with respect to European countries, Japan and the USA, where the target objective is to reduce oil consumption for power generation by 1990 to less than 40% of the 1981 figure and to less than 10% by the year 2000 (42).

53. African countries have fully recognized this world wide trend away from petroleum based power generation to a wider range of energy sources in which coal will play an increasing role in the future. The planning and development of new coal fired power plants on the African continent has recently been initiated in many African countries where coal is already available (e.g. Botswana, Swaziland, Zimbabwe, Morocco, Niger and others). But also in places where coal is not sufficiently available (or not yet found), coal fired powerplants are part of the longterm energy strategy if they can be positioned at the coastline, as for example in Egypt, where a coal fired powerplant is reported to be planned at the Gulf of Suez. This power station is expected to burn more than 2 Million tonnes of coal in the early nineties when 1200 MW will be installed. Thereafter, in the year 2000, 3,900 MW are planned for a coal consumption of 7.8 Million tonnes and even more thereafter (24). With regard to the preceeding chapter it appears to be obvious that most of these Egyptian coal requirements will have to be imported, and it appears to be logical that a major part of these steamcoal imports will come from newly developing African coal exporters such as Mozambique and Madagascar.

54. The substitution of petroleum based power generation and the anticipated increase in energy consumption as a result of growing industrial development will constitute a major challenge to create additional power generation in Africa. A major part of it will have to be based on coal or lignite where ever coal or lignite are available or where coal can be imported at competitive prices and transported at low costs which in most cases will be feasible for coastal African States.

55. Also intensifying or initiating geological and exploration work for the discovery of new coal or lignite resources and reserves for power generation and other usage (see below, sections 4.1.2. and 4.2) preferably in the neighbourhood of growing population centres, is highly advisable where coal or lignite deposits are not yet known or explored. Comprehensive resource identification and evaluation programmes in close co-operation between the Geological Surveys of African countries, existing international scientific institutions and experienced public and private industries at national, subregional and regional levels are urgently recommended. Pertaining details are discussed in the UNECA publication "Operational and Organizational Aspects"(52). This, of course, has a major bearing mainly on those countries, where exploration programmes on coal have not yet been carried out in the past (and does not concern so much those countries whose coal reserves are already known and which were subject of the recently established African coal inventory) (41). We have to bear in mind, however, that more than half of African member States and partly least developed countries could not be included into the inventory just undertaken. It is recommended that these countries should be the main targets for the suggested coal resource identification and evaluation programmes which would include the following basic steps of resource investigations:

(a) Comprehensive geological mapping of identified target areas;

(b) Geological scoutdrilling and trenching in order to support and verify geological mapping and to locate coal occurrences;

(c) Follow-up geological investigation work on identified coal basins by systematic core and rotary drilling programmes including geophysical logging, trenching and exploration shaft sinking for bulk sampling;

(d) Establishing basic coal quality and preparation testwork;

(e) Establishing pre-feasibility assessments.

56. These basic steps can be done by governmental agencies or subregional institutions and should involve potential investors, operating companies or power generation utilities as early as possible. However, the pre-feasibility assessment usually represents the latest point in time when the scientific emphasis should be shifting towards a more practical engineering and economically oriented approach which would lead into the feasibility assessment and planning

of the mine, preparation plant and infrastructure which in all cases should be undertaken by experienced mining operating and specialized companies with the support and backing of the respective utilities and under the observation, co-ordination and monitoring umbrella of the governmental ministries concerned. Further implications in this context will be dealt with in more detail in the aforementioned publication: "Operational and Organizational Aspects..."(52).

57. A short side step should be allowed here to refer to combustion technologies as far as they appear to be of importance to African countries. For the generation of electricity the coal is ground and burnt in a boiler to produce steam which is used to drive a turbine that generates electricity. The higher the temperature of the steam the more efficiently works the power station. Specific attention must be directed to air cooling systems and to the particulate emissions which can be reduced by certain appliances (e.g. electrostatic precipitators or bag houses). Most emphasis is directed towards reduction of sulphur oxide emissions. Thereby are beneficiation processes expensive and often ineffective since only p[illegible] the inorganic sulphur can be removed. The organic sulphur remains within [illegible]tock and [illegible]ul[illegible]in the flue gas (scrubbers). Other technologies are directed to control nitrogen[illegible] combustion.

58. In recent years major efforts have been directed in industrialized countries to increase efficiency and to mitigate environmental problems. The most important new technologies for a possible use in Africa are fluidized bed combustion and stabilized coal-in-oil suspensions which are utilized in oil designed power-stations (5 years industrial experiences in Peru) (44). The latter technology can help reduce foreign exchange burden for countries where coal is available and where oil burning equipment cannot be converted to direct coal combustion *. The fluidized bed combustion, may become of major importance for application under African conditions. While this method has been applied in principle for several decades in other industrial use (Petroleum refining, chemical, food industries), the application in coal combustion, where high heat release rates are involved, is comparatively new. It has been in smaller units as atmospheric pressure fluidized bed combustion in operation for several years in various parts of the world, and boiler vendors are prepared to extend certain plant guarantees. The first power plant of this type in Africa is operating in Niger (see section 3.4). The major advantage of this technology is that it facilitates the removal of sulphur within the combustion bed which may consist of crushed limestone accepting and absorbing sulphur oxide. It further operates at moderate temperatures (900°C), though high heat transfer efficiences are obtained, which prevent the formation of nitrogen oxides.

*Another alternative, which however appears to be still in an experimental stage and has not yet reached industrial proportions, seems to be the burning of water-coal suspensions. This method may have future application where long overland pipeline transportation of steam coal is used.

It, moreover, facilitates the use of high ash and sulphur containing coals or even discards from a preparation plant which appears to be of utmost importance while optimizing the use of coal, as will specifically be considered in section 4.3.

59. The next step in developing new combustion technologies would be pressurized fluidized bed combustion which would further increase the mentioned advantages and efficiency. However, the commercialization of this technology, which will be applicable for larger units as well, will require much more time to reach industrial maturity and can therefore not yet be recommended for application in developing countries in the near and intermediate term future.

60. It would exceed the frame work of this study if we should attempt to quantify the growing African demand for electric power, specifically the part to be established on the basis of coal and lignite. The contributing parameters with respect to the growing industrial development are too widely spread, and it should necessitate a comprehensive Africa wide assessment of the anticipated energy demand and supply development in the medium and longterm future. The combined UNDP / World Bank country Energy Sector Assessment programme which now covers nearly half of African countries, could serve as a basis for further subregional assessment studies and comprehensive regional evaluation programmes.

61. The proclamation of the eighties as the Industrial Development Decade for Africa (IDDA) emphasizes the importance of thriving industrialization in Africa (43). UNIDO is initiating a major survey on just this issue and specifically on the quantification of the expanding energy needs for the growing industrial development of African countries' economies. One of the present conclusions of these studies is that more detailed and comprehensive investigations, often in the absence of reliable statistics, are needed in order to establish actualized figures and realistic guidelines for improved energy planning for accelerated industrial development in Africa (43).

62. In view of these ongoing efforts and regarding the high amount of still required fact finding, this presentation will concentrate mainly on basic coal development related issues and on general methodology. More detailed operational and organizational aspects will separately be dealt with (52). However, "the elaboration of a coherent regional coal policy is an important prerequisite for the economic use of coal in Africa of which objective we must not loose sight" (43). This will remain a major task to be pursued within the studies on the development of coal in Africa. This important issue is further treated in the aforementioned publication (52).

4.1.2 Coal Gasification and Liquefaction

63.. Another important area of oil substitution are the technically feasible alternatives of coal gasification and liquefaction. Since the economics of these technologies, however, depend on specific not always compatible conditions, such as transportation costs for imported oil, quantities which the market could absorb, capital intensity, certain quality requirements of the coal to be converted, and a certain minimum size for an economically working plant, it appears that a wide spread application in African developing countries does not yet seem to be opportune. Bearing this in mind, a description of the available technologies and applicable methods should here be concentrated on a few in African States applicable methods.

64. Basically, there are three coal conversion processes available for selection:

1) Direct Hydrogenetion,

2) Coal gasification – Synthesis for ammonia fertilizer production and gasoline production, and

3) Coal Pyrolysis (Low Temperature Carbonization).

65. Direct Hydrogenation technologies have not yet been commercialized and consequently present a higher risk, so that this conversion route can not be recommended for implementation in the near future. However, some experts in this field believe that the direct coal liquefaction method will technologically and economically be leading in the long term future and thus recommend not to leave this method unchecked, especially if the implementation of the project should be invisaged at a time later than the year 2000.

66. On the basis of presently proved technology, the indirect coal conversion via gasification is generally regarded as feasible for African coals. The converted gas can be used for the Ammonia synthesis, i.e. for Fertilizer production and/or for gasoline, diesel and ke rosine production. Such a facility could be built in modulars and thus be adapted to market requirements. On the basis of a generally accepted status of knowledge and industrial maturity, this method is regarded most suitable for the conversion of African coals. The often high ash content as well as a high sulphur content can in all probability be digested by most gasification processes without unduly impairing the environment. In this connection also discards from coal preparation plants can be taken into consideration. The reactivities of the coals to be used for gasifying purposes, however, should be high, which means that they should have a high Exinite and Vitrinite content. The choice of a suitable gasifyer depends largely on the type of coal with respect to its mazeral content. The catalytical conversion of carbon monoxide to hydro carbons, as obtained by completely gasifying the coal and by adding hydrogen, is with the well known Fischer Tropsch process commercially proven for many decades.

67. It is recommended not to base the assessment on theoretical deliberations and on laboratory test work only but, at an appropriate stage of the investigations during the feasibility studies, to gain enough sample tonnage in order to carry out a series of industrial scale tests. This appears to be important not only with regard to gasification and liquefaction test work, but also in order to carry out industrial scale preparation test work in case discards should be considered for gasification, and in order to find the optimum yield and quality, and to carry out spontaneous combustion tests if the washed product should be considered for export (see below, section 4.3.1).

68. The third recommended route of feasibility assessments refers to Pyrolysis, the so-called Low Temperature Carbonization. Generally, high contents of Vitrinite and Exinite are required. But, by the same token, the ash content should be as low as possible. As reported above, such condition cannot be met if we use discards. Consequently, Pyrolysis might have a comparatively low chance of realization. However, this should remain subject to the necessary feasibility assessments (45), which should also include thorough market appraisals before entering into detailed technical planning work.

4.2 Substitution of Wood Fuel

69. Woodfuel is the traditional source of Energy in most African member States. Statistical information on wood fuel consumption in African households, however, appears to be inadequate and incomplete. Information on the growing desertification of African bush land around villages and towns seems to be sketchy as well. On the other hand, it is apparent and is common knowledge that desertification of wide areas in Africa progresses rapidly. In view of the deteriorating climatic impact, the needed reversal of African desertification calls for decisive measures on regional, subregional and national levels (46). It appears that massive re-afforestation programmes, exploitation of groundwater for irrigation, management of land use and cattle population, creation of woodlots around urban centres, etc., will possibly not suffice in time to halt or reverse the threatening development in the short term future. The overwelming problems of drought and famine call for emergency measures in many affected African countries and cause in some cases, in view of the limited resources, exigent long term oriented measures to be delayed.

70. On the other hand, the awareness for the gravity of the ecological situation Africa's appears to be growing, and it is undisputed that action of any practicable kind must be taken in order to halt and to reverse the obviously progressing ecological disaster.

71. In many industrialized and developing countries around the globe, coal is used for household energy, and it does not appear to be out of the way if, in view of the foregoing, also the use of coal for household energy should be promoted by African States in order to help reduce the devastating wood fuel consumption. This appears to be fully in line with the directives as given by the Lagos Plan of Action which calls for diversification of energy sources (46).

72. As shown in the preceeding sections (2.1 to 2.4) many African countries possess vast coal resources which are factually under-utilized. There are realistic chances that other African countries that do not yet have disclosed such resources could find coal or lignite if comprehensive efforts for exploration were initiated at national, subregional and/or regional levels in order to find new coal and lignite deposits which are still unknown at present.

73. The natural chances for woodfuel substituion by coal are basically prevailing in many African countries and need to be promoted and exploited as soon as possible. Studies of the UNDP/World Bank Team in Botswana (1) and of other institutions have shown that coal is well competitive as cooking (and heating) fuel in African households as shown in Table 4.2.1(1).

Table 4.2.1 Equivalent costs of cooking fuels in Gaborone households

Fuel Type	Energy Content	Fuel Unit	Retail Price	Cooking Efficiency	Energy Cost
	(Units/GJ)		(thebe/unit)	%	(thebe/useful GJ)
Coal a/	40.0	Kg	9	20	1,800
Fuelwood b/	68.0	Kg	10	15	4,533
Kerosene	28.7	Liter	51	30	4,876
LPG	21.6	Kg	104	50	4,493
Electricity c/	280.0	kWh	14	70	5,600

a/ Based on imported clean coal.
b/ Based on Gaborone retail price of P5.00/bundle of 50 Kg.
c/ Based on BPC residential tariff.

Source: (1)

74. However, it must be recognized that such cost comparison is restricted to commercially traded wood fuel and does not consider that a major part of firewood in Botswana, as in other African countries, is just being retrieved from the bush surrounding villages and towns. Consequently, the allocated price for firewood does not appear to be comparable with the price of coal as far as "collected" firewood is concerned. Coal cannot just be collected, but must be produced at some costs, which can certainly not compete with collected firewood.

75. Here appears to be the core of the problem. If we, in view of the aforementioned grave environmental problems, did not want to restrict ourselves to aiming at a woodfuel substitution of only approximately 10% (which appears to be the woodfuel consumption that is paid for by a solvent minority) then we must seriously consider effective incentives for the increased consumption of household coal. Even the average income of households in the suburban areas does not justify expectations for the implementation of coal stoves on the basis of a purely free market approach. The country population does certainly not have the means to buy stoves and to spend money on regularily burning coal instead of "collected" woodfuel. This in essence means a massive subsidy, at least initially, should seriously be considered if coal was to be introduced as a major wood fuel substitute. Subsidies should apply to:

a) Stove acquisition (sub-urban and rural) and to

b) Coal-nut sales to households of lower income (preferably rural).

76. But not only economic obstacles have to be to overcome if coal should seriously be regarded as a woodfuel substitute. It is by convenience in addition to cost reasons that wood users might oppose the coal stove, at least initially. Wood burning creates minimum amounts of ashes while coal burning creates much more ashes which must be handled on a day to day basis.

77. However, the quality problem can be mitigated by beneficiating the coal to coal-nuts with reduced ash and sulphur contents. The residual fines which are richer in ash and sulphur, can be added to powerplant feed or in the absence of such, could further be treated in order to produce smokeless briquettes for similar purposes (31). The coal beneficiation issue must professionally be handled by employing coal research institutions for testing and by the mining industry for planning, estimating and designing, constructing and operating a preparation facility.

78. But also the coal distribution functions, e.g. the supply to coal depots along existing railway lines and roads should effectively be delegated, preferably to wholesale enterprises. Also the final retail distribution to consumers should be initiated rather with the aid of private enterprises. However, the subsidization approach in order to reach also parts of the rural population with low income, would probably require specific measures or a separate organization for distribution.

79. Finally, reference must be made to the cultural and social obstacles that will doubtlessly oppose the massive introduction of coal fired stoves into African households. A fire place for cooking the meal in the evenings is certainly a focal point for comfortably assembling the family. However, with growing education and environmental awareness and with appropriate stove designs which leave the fire of a stove partly visible, as it is practised in the UK and in West Germany for many decades, the aforementioned obstacles should not be insurmountable. Moreover, a carefully planned and executed education and information campaign, supported by coal stove demonstration centres, should be linked with the distribution organizations to ensure efficacy of such woodfuel substitution programme.

4.3 Coal Exports

4.3.1 Project Optimization

80. The volume of the world's coal trade has risen from 197 Million tonnes in 1975 to 300 Million tonnes in 1984 (4.8% growth per year) and is expected to raise further to more than 560 Million tonnes in the year 2000 (at least 4.3% growth per year) (40). The major importers will be OECD Europe, Japan, Canada, East and other Asia, Africa, Latin America and central planned economies, the major exporters will be Australia, United States, South Africa, Poland, Canada, the Peoples' Republic of China and others (40, Table 2-6, Page 113). As dealt with separately, Africa's overall coal export will amount to approximately 65,83 Million tonnes in 1990 of which developing countries will share 0.83 Million tonnes (41) which mainly serve inter African trade. North and Western African countries will in all probability import approximately 8.2 Million tonnes in 1990 which will mainly originate from major coal exporting countries such as USA, Poland, Australia, USSR and West Germany (24). As explained elsewhere (52)and in the recent inventory of African coal resources (41), the tremendous Southern African coal potential will not have been appreciably mobilized by 1990 for a sizeable share in the international coal markets.

81. The importance of coal exports for African developing nations with respect to the creation of jobs and earning of most needed foreign currency cannot be overemphasized. The growing coal import requirements of industrialized nations (mainly Europe and Japan) will create an international market scenario in the future which should not be impossible for competitive new comer exporters to enter. Striking examples for the successes of such new comers since the early seventies are Western Canada, Poland and others, while, even since the development of the oversupply situation in the international coal markets in the

early eighties*, a developing nation like Columbia in South America aggressively found its entrance into these coal markets. Presently, there is still a serious oversupply situation prevailing as in most raw material markets in the world. But this should not prevent enterpreneurial initiative from penetrating the markets by competitive coal export projects in time in order to acquire a market share which may become profitable in the long run. Coal projects for export purposes usually require several years for development (3 to 7) depending on size and circumstances. The market situation might have changed when project completion is accomplished, and the oversupply capacity might have been diminished or even used up.

82. Most experts in industrialized countries predict further steep increases of the international demand for coal, and most exporting and importing countries are energetically expanding their harbour facilities, anticipating even increased growth for coal trade in the intermediate and long term future (47). The capacity of the unloading facilities of the above mentioned coal exporting nations will possibly be increased from 491 Million tonnes per year in 1984 to 600 Million tonnes in 1990 despite an excess capacity presently of 50%.

83. The general trend goes to larger sizes of bulk-carriers above 100,000 dwt. The world fleet of bulk carriers over 100,000 dwt grew from 3 in 1967 to 425 in 1982 and is further growing. More than one third of the sea going world coal trade was handled by these shipsizes in 1983 (47). It is obvious that also new African harbours for coal transshipments must reliably be available for these large shipsizes in order to be internationally competitive.

84. Coal prices in the international markets and costs are the main indicator for the competitive situation. International steam coal prices were at their peak following the "Oil crisis" in 1973/74 and were booming in the wake of increased oil substitution tendencies during economic prosperity up to 1981/82. While FOB steam coal prices rose form a range of US$20-30 in 1977 to US$40-60 in 1982, they fell back during the ensuing recession years to a range of US$30-50 in 1983 and have not substantially recuperated since. Thereby are prices FOB Richards Bay, South Africa, at the lower end of the international scale while prices FOB Gedansk, Poland, are at the higher end. Australian, US and Canadian steam coal brands normally establish their FOB prices between these extremes. The reasons for such FOB price differentials in the international steam coal markets are manifold. Quality divergences and the differing sea-route distances to consumer ports, as well as politically motivated "rebates" contributing to acceptable CIF prices are of importance. (45).

---

* The world's seaborne export capacity was estimated at 350 Million tonnes per year in 1981 (48), while the seaborne coal trade was only slightly above 200 Million tonnes in 1981. The excess capacity is still prevailing in 1985 despite an increase of the seaborne coal trade (230 Million tonnes).

85. For coal importers the CIF prices are of decisive importance, but also the various quality parameters according to the end-use of the coals, must be taken into consideration. Average CIF prices in Europe (ARA) amounted in 1983 to approximately 51US$ per tonne for steamcoals and 66 US$ per tonne for coking coals. The freight costs in 1983 were varying between 6 and 11 US$ per tonne depending on shipsizes and overseas distances (e.g. USA or Australia) (47), however, the freight market is, due to overcapacities, presently depressed as well. Normally cost covering freight values are higher by probably 30 to 50% or even more.

86. But not only the sea freight costs are decisive for the competitive situation of a potential coal export area, also the inland transportation costs play a dominant role. Consequently coal exporting countries have developed low cost - large quantities unit train traffic systems in order to minimize land transportation costs. A unit train needs not to be uncoupled at the mine site for loading the coal, as well as at the harbour site for unloading on the stock yard and into sea going vessels and thus minimizes cycle times.

87. As a generally applicable rule of thumb in assessing competing alternatives for transporting large quantities of coal by rail and connected harbour costs, one can expect that:

- Unit train transportation would be economically advantageous on a tonne kilometer basis in comparison to conventional rail traffic (order of magnitudes 0.017 US$ per tonne kilometer in comparison to more than double this amount).

- Rail transportation using an established infrastructure and traffic pattern would be less costly than a newly established rail connection of similar length;

- Harbour loading into seagoing vessels would be cheaper in modern bulk loading and storing facilities, handling large quantities for large ship sizes, than in conventional harbours with smaller dimensions (order of magnitude 4-6 US$/t in comparison to 7-9 US$ per t).

- Modern handling facilities that have existed already for some years and need only to be expanded should offer lower handling rates than completely new investment sites.

88. The foregoing explanations make it clear that newly to be established coal export facilities in Africa, as elsewhere in the world, from the mine site over inland transportation routes to suitable harbour facilities, require the exploitation of all possible project optimization measures and a certain

minimum production size to achieve maximum economies of scale and a sufficient profit per year in order to pay back for the major amounts of infrastructure investments that are unavoidable if penetrating the market under todays competitive conditions is intended. For instance, the project size for an export project in Mozambique would have to be large enough in order to pay back for additional railway infrastructure (574 Km from mine site to Beira) in comparison to an island such as Madagascar, where the distance to the harbour may be exceptionally short. It appears to be inescapable to prepare for a mega project size, if the new establishment of competitive coal exportation is contemplated under "average", i.e. not extraordinary advantageous conditions. Production sizes of more than 5 million tonnes yearly capacity, as in the EL Cerrejon project in Colombia, must be considered. The initial investment for such a mine in Southern Africa (openpit with draglines and/or shovels, preparation plant, workshop etc.) might amount to 30-70 US$ per annual tonne capacity; to which the infrastructure (rail, harbour, townsite etc.) would have to be added, however, according to local conditions the specific investment figure can exceed this rule of thump range considerably. For the entire EL Cerrejon project, including all infrastructure, an overall investment of the order of magnitude of 3 billion dollars will have to be spent for reaching the final capacity of 15 Million tonnes per year by 1989 (49). This order of magnitude, however, may characterize the utmost upper limit of prudent investments for coal, which might not have to be approached under Southern African conditions.

89. The utmost tough competition between coal exporting establishments world-wide indicates clearly that only the maximum improvement of all possible project areas regarding cost minimisation and revenue optimization must come together in order to lower the treshhold for a viable project realization. In this connection openpit mining generally appears to be preferable to underground mining. Mining at low waste coal ratios in openpits is generally economically preferable to mining at high waste coal ratios. Underground mining in shallow depths is mostly done at lower costs than mining in greater depths, etc. A most important factor for project optimization, however, lies in the successful selection and involvement of an experienced operating company with a proven track record in high performance - low cost coalmining operations.

90. A further important possibility to noticeably improving the earning power of a coal export project is by using the <u>rejects of the preparation plant.</u> In order to produce the required coal quality for export markets, the obtainable yield in beneficiating the coal blend is in most African coals only 50%. This means that the other 50%, which could also be regarded as fuel, containing a gross heating value averaging often near to 20 MJ/Kg, should not be disposed of on a waste dump, subject to the perils of spontaneous combustion. The question arises what such a fuel material, often containing relatively high sulphur contents, could be used and sold for.

91. The first possibility to be regarded should be power generation. However, the available markets could take only a minor part of the available discards. The question whether power generation could be expanded in order to export such power beyond the respective country's borders should seriously be checked. Also the creation of an exportable steam coal product should be checked if the prime product of the preparation plant was coking coal (Zimbabwe, Mozambique). It would probably be prudent to also check whether the available inland market for the mentioned rejects should restrict an acceptable quantity of such a fuel and consequently limit the size of the export coal project (Swaziland). Also the options of using suitable discards for coal gasification and liquefaction should be checked (see section 4.1.2).

92. Optimization does not mean, however, that sophisticated, highly mechanized mining methods should be pursued for small or medium scale underground coal mines. As experienced in Zimbabwe and Swaziland, the very simple but effective lay out of some African underground mines shows that the operating costs appear to have been minimized by applying a minimum of investments and equipment installations. Such low cost mining, if effectively managed, can successfully compete with highly mechanized mines of similar production. (100,000 to 700,000 tonnes per year range). It has to be mentioned, nevertheless, that in larger mines, as mostly required for export purposes or large scale power generation, the safety problems connected with large labour crews moving into and out of an underground coal mine, force the mine planner to increase the degree of mechanization in order to increase performance and consequently to reduce the number of underground labour force. A qualification has to be made with respect to the general level of labour costs in a country. In industrialized coal producing countries the level of average labour costs for underground (and openpit) mining appears to be higher than in developing countries. It goes without saying that the level of labour costs determines the treshhold, when mechanization commences to make economic sense.

93. The operational and organizational requirements for a mega coal export project are demanding and necessitate, as mentioned above, the involvement of experienced internationally recognized project management and operating establishments. Moreover, a conducive politico-economic climate may be regarded a further precondition for the attraction of international coal consumers and investors that must have confidence in the long term viability of the project in order to participate in its investment. The operational and organizational aspects of large coal mining projects are discussed in detail in the publication "Coal in Africa, Basic Proposals for its Development, Operational and Organizational Aspects of Increased Coal Utilization" (52).

4.3.2 Penetrating International Markets

94. The reader should not be discouraged by the foregoing assessment. It is the opinion of the author that in view of the growing volume of the international coal trade under longterm aspects, there may be realistic chances for successfully penetrating the international coal markets if a professional and pragmatic approach towards solving the problems were adopted. Even if we consider the oversupply situation in the international coal markets, as mentioned above, many factors, can play a positive role in the course of the promotion of a new coal export project.

95. In 1983, at the initiative of the Botswana Department of Mines, a project proposal for the Evaluation of Export Opportunities for Southern African Coal producers was made within the framework of the SADCC co-ordinated programme of action (50). The results of this highly specialized study will have to be assessed for a final judgement. However, certain basic issues and parameters are known allready now which could contribute to a better understanding of the involved subject matter.

96. The geographically favoured countries like Madagascar, Mozambique and Swaziland may have the best chances to penetrate the international coal markets with their specific coal brands:

Mozambique - with excellent quality coking coals and with low sulphur steam-coals (by-products of the preparation process?),

Madagascar - probably with low sulphur steamcoals, and

Swaziland - with low sulphur anthracite and semi-Anthracite.

97. The landlocked Southern African countries, e.g. Botswana and Zimbabwe, may in all probability have to wait until the year 2000 despite possessing vast coal reserves at competitive coal qualities. However, the long railway distances to tidewater and the necessary costly infrastructure investments appear to be prohibitive for the build-up of major coal export capacities in these countries at the present time and within the intermediate term future (20, 45).

98. One very important factor is the quality of the coal, specifically if coking coal is considered for development. In the case of Mozambique, the qualities of this coal appear to be in demand for countries that do not have own coking coal resources with a high blend potential. In this connection Mediterranean European countries and North and West African countries could be potential customers and importers promoting the development of an African coking coal project. Similar conditions apply to low sulphur steamcoals which are continuously in demand.

99. Another factor is the possibility of aggressively penetrating the international market if the respective export coal project proves to be competitive, so that during several initial years a low price scenario can be outlasted. The mega project of EL Cerrejon appears to be a striking example for such a daring strategy. As it was recently published (51), the selling prices that are required for a decent return on investment are assessed to be much higher than the present international FOB price levels (near 30-35 US$ per tonne) facilitate. If 43 US$ per tonne were obtained, the return on investment would only be 5%, which surely is not yet acceptable for normal investors which require 15%. The name and financial potential of Exxon, as well as the long term outlook for coal, appear to have convinced the investors and international banking institutions to support such a project despite its marginal financial features at the present time.

100.. A further approach to aggressively penetrate the international coal markets is the attraction of potential customers to directly participate in the financing and development of the coal export project by the acquisition of a share in the mining venture for the exploitation of the coal resource. In this way, the participating project partners do not only acquire the right to receive a certain share of the production (at internationally competitive prices), but they also would have to accept the obligation to take a minimum share of the production and to pay for their share of the operating costs.

101.. Due to the ever rising investment cost figures for (low operating costs) large tonnage openpit mining projects (including beneficiation, transportation and loading into seagoing vessels) few mining companies in the world appear to be prepared under the circumstances to venture such an investment on their own. The larger an investment for a mining project, the more important it is to distribute and to diversify the investment burden and risk on many shoulders. In view of the inevitable ups and downs in the international coal markets it moreover appears to be of growing importance to include into an export oriented mining venture and into its financing scheme several major customers in order to secure the required base sales tonnage at long term contract prices which are needed to secure the financing of a mega project.

102. A successfully proven mode of organisation for such a major mining enterprise is the joint venture consisting of investors, mainly coal consumers. Also the government, providing the coal in the ground and considerably contributing to the exploration results, would probably insist in a sizeable participating share in such a joint venture. We conclude here that with an appropriate professional and pragmatic approach there appear to be ways and means to implement an African coal export project even under todays depressed market conditions. Due to the lengthy time requirement for the exploration and development of a major coal export project, an anticyclical timing for commencing preparatory and development work appears to be even advisable in order to have reached production when the coal price upheaval finally occurs.

5. List of Reports and Documents

That were available to the author and which have been used for the elaboration of this report. The sequence of the numbers indicate the sequence during the preparation of the various sections.

1. UNDP/World Bank: Botswana, Issues and Options in the Energy Sector, 1984.

1a. Botswana Department of Mines, Annual Report, 1983

2. Estimates of the author, based on personal information during recent missions in 1984 and 1985.

3. Department of Geological Survey: The Coal Reserves in Botswana, 1984.

4. Malawi Geological Survey: various publications by J. Chatupa, 1983/84.

5. UNDP/World Bank: Malawi, Issues and Options in the Energy Sector, 1982.

6. UNDP Country Report Mozambique, 1985.

7. UNECA: Current Status and Future Prospects for the Development of Coal in Africa, 1983.

8. N.M. Murray and A. Granville, Mineral Bureau of S.A. (German) Magazine Glueckauf 118 (1982) No. 4: The Coal Mining Industry in South Africa (German language).

9. Mining Annual Review, published by Mining Journal, London, 1985, 1982, 1981.

10. Mining Journal, London, March 1985.

11. P.J. Hugo, Minerals Bureau, Johannesburg; The South African Coal Industry, June 1983.

12. W.S. Lyimo, Tanzania Ministry of Minerals: Tanzania Coal Development, June, 1983.

13. A.O. Mansur, Egyptian Geological Survey: An Assessment of the Potential of Coal Deposits in Egypt, and Future Prospects, June 1983.

14. UNECA: Various documents from the Regional Workshop on "The Role of Coal in Accelerated African Economic Growth", July, 1983.

15. H.J.K. Koesser, W. Siemens: The Mining Economy in the Republic of Niger, (German) Magazine Glueckauf, 1985.

16. Nigerian Coal Corporation: Information on the Nigerian Coal Industry, 1982.

17. Republic of Zambia Ministry of Mines, Geological Survey Department: Coal Exploration in Zambia, (1983 position and projections for the future).

18. H.H. Palloks, Zimbabwe Geological Survey: An Assessment of Some of the Coal Deposits in North-West Zimbabwe, 1984.

19. B. Barber, Zimbabwe Geological Survey: Coal Resources and Utilization Study, 1984.

20. Montan Consulting GmbH and Zimbabwe Ministry of Mines: Final R eport on Coal Resources and Utilization, Pre-Feasibility Study, 1983.

21. Wankie Colliery Co. Ltd.: Documents and Publications, 1984, 1985, (partly unpublished).

22. US Bureau of Mines: Minerals Yearbook, 1981.

23. UNDP/World Bank: Zimbabwe, Issues and Options in the Energy Sector, 1982.

24. Zaki El-Hewchi, Chemicoke. Egypt: Prospects for African Co-operation in Coking Coal for Iron and Steel and related Industries, prepared for UNECA, 1983.

25. British Mining Consultants Ltd.: Feasibility Study for the Rehabilitation of Hwange Collieries Ltd., Volume 1, Executive Summary and Financial Analysis, December 1984, (unpublished).

26. National Energy Council of Zambia: Energy Production and Consumption in Zambia 1978-1983.

26a. UNDP/World Bank: Zambia, Issues and Options in the Energy Sector, January, 1983.

27. Friedensburg-Dorstewitz: The Mining Economies in the World (in German Language), 1976.

28. UNECA et Congrès Geologique International: Carte des Dépos Hauilliers en Afrique, 1964.

29. Barclays Botswana: An economic Survey and Businessmans's Guide, 1982.

30. African Business, London, June 1984.

31. SADCC Project Proposal No. 281: Investigations of Coal Briquetting in Zambia, 1985.

32. World Coal, Vol. 7, No. 7, Nov./Dec. 1981.

33. World Bank: Study on Existing and Planned Export Coal Mines in the Republic of South Africa, 1983, (unpublished).

34. A.T. M. Mehliss: South African Coal, Energy Minerals, 1985.

35. Netherlands Economic Institute: Zimbabwe Coal Transportation Study, May, 1985.

36. South African Operating Companies for Coal Mines and Projects: statistical information on mining engineering and economics of coal mines and projects in Swaziland, Malawi, Botswana and Zimbabwe (unpublished), 1985.

37. South African Institute of Mining and Metallurgy, Monograph Series No. 4, Increased Underground Extraction of Coal 1982.

38. Chamber of Mines of South Africa: ninety-fourth Annual Report, 1983.

39. Gewerkschaft Exploration (Exploration and Mining): Bituminous Coal in South Africa, (German language) Duesseldorf, FRG, (unpublished), 1972.

40. Massachusetts Institute of Technology: Coal - Bridge to the Future; Report of the World Coal Study, Boston, 1980.

41. UNECA, G. F. Lange: Inventory and Assessment of African Coal Resources Production and Trade in the Context of Regional African Development, 15 November 1985, ECA/NRD/ERU/COAL/280/2/85, including 40 sources of documentation which are listed before.

42. R.H. Shannon: Handbook of Coal Based Electric Power Generation, USA, 1982.

43. H.J. Laue, T. Balabanov, UNIDO: Energy Planning for Industrial Development, 1985.

44. Newspaper article in EL Comercio, Lima, Peru, of 22 June 1985, as transferred to the Author by Grundstofftechnik GmbH, Essen, Germany, in July, 1985.

45. UNECA, G. F. Lange: Conceptual Contribution to the Reorientation of the Strategy for a Coal Export and Utilization Project in Botswana, 16 December 1985 (ECA/NRD/ERU/COAL/280/3/85).

46. Organization of African Unity: Lagos Plan of Action for the Economic Development of Africa 1980-2000, 1980.

47. H. J. Mareyen, J. Brinkmann: Steinkoblenseeverkehr in der Welt (Hardcoal seagoing traffic in the World), Volks-und Energiewirtschaft, Glueckauf 121 (1985, No. 16).

48. H. Mollanby-Lee, NCB; Coal prices improve but oversupply continues, Engineering and Mining Journal, March 1985.

49. J. R. Burger: Cerrejon - Coal from Colombia, E. and M.J., April 1985.

50. SADCC Energy Project of Regional Interest: Evaluation of Export Opportunities for Southern African Coal Producers, September 1983 (not finalized).

51. J. C. Todd: Cerrejon Profitability snags on low prices and lagging sales, E. and MJ, September 1985.

52. UNECA, G. F. Lange: Coal in Africa, Basic Proposals for its Development-Operational and Organizational Aspects of increased Coal Utilization, 16 December 1985, (ECA/NRD/ERU/COAL/280/5/85).

6. Abbreviations as used in this Report

ARA	Amsterdam, Rotterdam, Antwerpen
BPC	Botswana Power Corporation
C	Degree temperature in Centigrade (Celsius)
Cbm	Cubic meter
Cby	Cubic yard
CIF	Cost, Insurance, Freight
d.b.	Dry basis
E	Emalangeni (Swaziland currency, same value in US$ as Rand)
EEC	European Economic Community
FOB	Free on Board
FRG	Federal Republic of Germany
GJ	Giga Joule, heat value (4.18706 Kcal/Kg)
IDDA	Industrial Development Decade in Africa
K	Kwacha (Malawi and Zambian Currency, MK = 0.62 US$ (July 1985)
	ZK = 0.50 US$ (August 1985)
Kg	Kilogram (1000 gram)
Kcal/Kg	Kilogram Calory per Kilogram, heat value
LPG	Liquid Petroleum Gas
MJ/Kg	Mega Joule per Kilogram (4.18706×10^{-3} Kcal/Kg), heat value
MS	Manshift
MW	Megawatt, heat rating
NCB	National Coal Board (UK)
NE	North-East
NOx	Nitrogen oxides (NO, NO_2, etc.)
OECD	Organization for Economic Co-operation and Development
ROM	Run of Mine (Coal)
SADCC	Southern African Development Co-ordinating Conference
t	Tonne (metric 1,000 gram)
thebe	1 thebe = 0.01 Pula, Botswana Currency (1 Pula = 0.87 US$ in April 1985)

t/MS	Performance in tonnes coal per manshift
UNDP	United Nations Development Programme
UNECA (ECA)	United Nations Economic Commission for Africa
UNIDO	United Nations Industrial Development Organization
W	Watt, heat rating
Z$	Zimbabwe Dollar = 0.63 US$ (Sept. 85).